AS-level Topology Collection through Looking Glass Servers

Zeqian Li
Computer Science
Worcester Polytechnic Institute
Worcester, MA
zli14@wpi.edu

Anqi Lu
Computer Science
Worcester Polytechnic Institute
Worcester, MA
alu@wpi.edu

Wei Xiong
Computer Science
Worcester Polytechnic Institute
Worcester, MA
wxiong@wpi.edu

***Abstract*—The goal of our project is to replicate and compare the results from paper AS-level Topology Collection through Looking Glass Servers by Khan et al. [1]. Several studies have pointed out the incompleteness of the Internet topology researchers have found and pieced together so far. In this study, we explore one of the AS-topology collection method – Looking Glass (LG) servers with the hope to discover AS links that were not found by other AS topology collection methods. After querying LG servers we collected, we discovered 28K AS links and 5.9K ASes that were hidden from other resources.**

***Index Terms*—autonomous systems, looking glass servers, network topology, web scraping**

I. Introduction

A. AS-level Topology

The Autonomous Systems (ASes) are collections of connected Internet Protocols routing prefixes, operated by one or more network administrators. An autonomous system is assigned with a globally unique number, called Autonomous System Number (ASN). Border Gateway Protocol (BGP), as the de facto inter-domain routing protocol, provides each AS a) internal information about the reachability of all routers within one AS and b) external information about the reachability of neighboring ASes [2]. AS-level topology collection is an ongoing effort for its importance in various studies, including Internet topological property analysis, AS relationship reference, network topology simulation, and new protocol and improvement evaluation [1].

Three categories of methods have been widely used by researchers to collect AS-level topology: a) BGP based, b) Traceroute, and c) Internet Routing Registry (IRR).

1) BGP based methods gather AS information from BGP feeders, large ASes that share their BGP traces to BGP collector projects. UCLA Internet Research Lab (IRL) [3] published and updated a series AS topology datasets collected by RouteViews [4], RIPE-RIS [5], Packet Clearing House (PCH) [6], and Internet2 [7]. Khan et al. referred to the collections of these datasets collectively as IRL dataset. The IRL dataset was last updated in Januray 2015. We found 573 K AS links and 60.3 K ASes in the dataset.
2) Traceroute method finds AS links from traceroute paths. Ark [8] and iPlane [9] were two datasets Khan et al. found and compared with in this category. Ark dataset has been updated continuously. By November 2018, we found 748 K ASes links and 66.9 K ASes. iPlane was lastly updated in August 2016 and we found 439 K AS links and 38.1 ASes.
3) Internet Routing Registry (IRR) [10] is a globally distributed database that stores AS routing and address information. IRR was created to ensure the stability and consistency of routing by different network operators. IRR dataset is also update-to-date. We found 237 AS links and 47.8 ASes.

Khan et al. pointed out that all three methods have their own limitations [1]. BGP based methods suffer from routing policy filters and best path decision made by other ASes. Traceroute methods might generate false results due to inaccurate IP-to-AS mapping or non-responsive hosts. IRR is known to contain stale and outdated information. Additionally, many ASes, except in RIPE region, do not use IRR to register their information. Therefore IRR is potentially biased towards RIPE regions [1]. Because of these limitations and the colossal size of the Internet, the AS-level topology researchers have gathered so far is still very much incomplete, as indicated by various studies [11] [12].

B. Looking Glass Servers

Looking glass (LG) servers are limited, read-only web portals that can be accessed remotely to view BGP routing tables of the ASes in which the server resides [1]. Even though other methods have collected a lot of data already, the large number of LG servers gave LG servers a slight advantage. Zhang et al. found that looking glass snapshot provided more unqiue AS links than route server [13]. They suspected that Internet hierarchy and routing policies resulted that most AS paths go up to the top tier ISP and then go down to the destination ASes. In the way of going down, these AS paths overlap. Unique contribution as a result, happens mostly before the AS path reaches the top tier ISP [13]. Furthermore, since LG servers resides on many individual ASes, using LG servers might address or mitigate the shortcomings of authoritative dataset IRR – being speculated to be biased towards RIPE region. We hope LG servers could help discover hidden links that other methods were not able to find.

In this project, we queried over 1.2K looking glass servers, collected 64K ASes and 135K AS links in total. We made comparisons with other AS topology datasets: IRL, Ark, iPlane, and IRR, and found 5.9K unique ASes and 28K unique AS links through LG servers. In 2013, Khan et al. found 686 unique ASes and 11K unique AS links. These results verified our hope and speculation that LG servers are useful and valuable in AS topology collection, and are aligned with what the original paper authors had found. Furthermore, we found much more unique ASes and AS links compared with what Khan et al. had discovered as the Internet had grown enormously over the past five years.

II. Background and Motivation

Khan et al.'s work can be summarized into the following steps:

- Sent `show ip summary` and `BGP neighbor ip advertised route` query to LG servers
- Retrieved latest datasets from other methods at the time (2013)
- Created AS degree distribution from AS links collected using LG servers and other methods
- Compare the their results with those of other methods at the time (2013)

```
BGP router identifier 193.110.159.1, local AS number 24770
RIB entries 1318244, using 141 MiB of memory
Peers 10, using 89 KiB of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
87.120.6.65     4 34224 24060647  625378        0    0    0 11w4d05h Idle (Admin)
87.120.206.81   4 34224 1472485  625364       0    0    0 11w4d05h Idle (Admin)
87.121.6.193    4 34224 1157062  625365       0    0    0 11w4d05h Idle (Admin)
87.121.7.113    4 34224  944845  859338       0    0    0 42w4d09h        805
87.121.83.101   4 34224 28960741  625093        0    0    0 11w4d05h Idle (Admin)
92.247.141.209  4  8717 2565652  859356       0    0    0 02w1d07h     11697
92.247.141.213  4  8717 189975892  859300        0    0    0 01w3d05h    717316
185.44.118.249  4 204639 41328274  735877        0    0   58 08w6d21h    721343
193.169.198.10  4 15669 14305292  858392        0    0    0 03w5d10h     67872
193.169.199.10  4 15669 14437801  858333        0    0    0 04w3d05h     67798
```

Fig. 1: A sample result of the `show ip bgp summary` command.

```
   Network          Next Hop            Metric LocPrf Weight Path
*> 9.9.9.0/24       192.203.154.253                        0 42 19281 i
*> 14.128.4.0/24    192.203.154.46                         0 9790 9503 55759 i
*> 14.128.6.0/24    192.203.154.46                         0 9790 9503 55759 i
*> 14.128.7.0/24    192.203.154.46                         0 9790 9503 55759 i
```

Fig. 2: A sample result of the `BGP neighbor ip advertised routes` command.

Khan et al. found 1.2K servers but only 420 of them were in operation at the time, in the month of March 2013. The authors used two commands to query the LG servers to gather AS link information: `show ip summary` and `BGP neighbor ip advertised route`. Fig. 1 shows an example data from `show ip summary` command. In this sample result, the first line indicated LG's own AS number. However, not all LG servers that responded to summary command included this line. The following table shows information about this AS's neighboring ASes. Highlighted in yellow are neighboring AS numbers which were collected to form AS topology. Note that the column didn't align with its header "AS" in this example. Similarly, Fig. 2 shows a sample result from `BGP neighbor ip advertised routes` command. This table contains information of the announcements advertised by this LG router to its peering BGP routers. From the AS Path, we can infer the neighboring AS links. For example, in Path `42 19281 i`, `42` and `19281` are neighbors and `19281` and `i` (own AS) are neighbors. From this path, we could thus collect 2 unique AS links.

The authors also collected datasets that used other AS-level topology collection methods, specifically IRL (BGP based), Ark and iPlane (Traceroute based), and Internet Routing Registry (IRR), which we have introduced in previous section. They then compared the number of ASes and number of AS links with those that were found in the other datasets, illustrated in table IV and table VI. In addition, they summarized top 10 ASes in terms of the number of newly discovered AS links through LG servers, and compared the results with what have been found in IRL dataset in table II. From these AS links, the authors created AS degree distribution using complementary cumulative distribution function (CCDF), illustrated in Fig. 3b, 4b, and 5b.

III. Scope Summary

The authors published two list of URLs of LG servers, representing 242 LG servers supporting `show ip bgp summary` command and 131 LG servers supporting `BGP neighbor ip advertised routes` command respectively. We parsed out the two lists of URLs individually and tried `URL open` command on them. We found that only 111 out of 242 LG servers that supported BGP Summary command could be opened; 58 out of 131 LG servers that supported BGP Neighbor command could be opened. These numbers fluctuated in a small range since some LG server sites weren't stable. As we can see, only half of the LG servers that the authors collected were even running on the Internet, let alone the ones that still supported the command or providing accurate information. We thus see the need of collecting more and updated set of LG servers that could be used to construct the Internet AS-level topology to compliment the loss of old sites and also investigate how much has the Internet grown since 2013. Therefore, we found BGP Looking Glass Database [14] that provided over 1k LG server links. We parsed out 1276 URLs from this database. Overall, our dataset is the the union of URLs the authors provided, and all the URLs from BGP Looking Glass Database.

After we completed data collection from LG servers, we downloaded the latest datasets from the resources mentioned in the original paper. We followed the methods used by the authors to compare the AS-level topology collected from LG servers and from other resources. We also compared the data collected by us with the data collected by the author to come up with some primary results of Internet growth.

Overall, our report will include the comparison of AS topologies derived from LG servers and other resources in 2018, replicating what the authors did in 2013. Furthermore, we will compare AS topology collected by us in 2018 with the one collected by the author in 2013.

IV. Experimental Setup

A. AS Topology derived from LG servers

We built a tool to automatically send request and fetch data from LG servers. The working flow of the tool is as below.

1) URL Validation: Not all URLs in our collection can be opened all the time. We set a 10s timeout for each attempt to open one URL. If a URL could not be opened in 10 seconds, we considered it as a dead link and it will be skipped.

2) Search BGP commands: For the LG servers that can be opened within 10 seconds, we checked whether they supported `Show ip bgp summary` command or `BGP neighbor ip advertised routes` command. We decided to send request only to those URLs that used http form request. After we find out all the URLs that contain form tags, we applied a more detailed search on the attributes inside those form tags because there may have been more than one form tags inside a html structure.

3) Send HTTP requests: For the LG servers that supported `Show ip bgp summary` command or `BGP neighbor ip advertised routes` command, we sent corresponding HTTP requests to all the routers listed on the LG server web pages. From those form attributes we found in the previous step, different strategies were applied to those attributes. In order to send correct http request, we need to find the destination we want to send request to, the type of the request, and the data sent with this request. The `form action` corresponded to endpoint, which would be translated into destination URL when combined with the original URL. The type of request corresponded to `form method`: usually POST or GET. Finally the data sent with this request corresponded to `attribute: value` pairs from `form option` or `form select`. Those different pairs may contain a lot of attributes like BGP related request, different individual routers, ipv4 or ipv6, etc. We iterated through all the possible combinations of different request, routers, and ipv4/6 from these pairs and send requests based on all the possible combinations as query entries to get as much results as possible.

4) Process HTTP responses: For all HTTP responses sent by LG servers, we extract AS numbers and AS links from them. For the results returned by BGP Summary command (Fig. 1), we stored AS and its neighbors information as a JSON object, with the key as own AS number and the values an array of neighboring AS numbers. We first used rules to determine the format of a table, parsed out the AS number in each row, and added it to the array of neighbors. For results returned by BGP Neighbor command (Fig. 2), we extracted AS pairs from `AS Path` column and stored those pairs. From those AS pairs we could then discover the numbers of ASes and AS links. The http responses had different formats for two different BGP commands. For `Show ip bgp summary` command, one column in the response contained all the AS numbers of its neighbors. For `BGP neighbor ip advertised routes` command, the returned response did not directly include neighbor attributes, but instead it listed the AS path to this specific AS. In fact, neighbors can be inferred from this AS path by pairing the adjacent AS numbers. In this way, we divided all the AS paths into BGP pairs to find direct neighbors of a specific AS.

Our tool waited 10 seconds before sending another query to the same LG server to avoid overloading the servers. We ran the tool once a week and the collected data in a period of 3 weeks. Through this whole process, we collected 64K ASes and 135K BGP links.

B. Other AS Topologies

We also collected the lastest AS topologies from other resources:

1) **IRL** [3] was last updated in January 2015. It had 60.3K ASes and 573K BGP links.
2) **Ark** [8] was last updated in November 2018. It had 66.9K ASes and 748K BGP links.
3) **iPlane** [9] was last updated in August 2016. It had 38.1K ASes and 439K BGP links.
4) **IRR** [10] was last updated in November 2018. It had 47.8K ASes and 237K BGP links.

Those datasets are open sources, so we used a script to fetch their daily or monthly data. Those data usually came in the form of database files with over 100,000 lines in one file. They all have guidelines indicating information on AS number or AS path or neighbors. Based on this, we were able to filter out the needed information to find AS pairs. Since each dataset used different database system, they came in different format. Each dataset needed a different data parsing tool.

V. Results and Comparative Analysis

In this section, we are presenting the results we found from looking glass servers. We compared our results with those from other AS toplogy datasets: IRL, Ark, iPlane, and IRR. We also compared our results with what Khan et al. had found in March 2013.

A. Overlapping/Unique AS Links

The author summarized the top 10 ASes in terms of the number of newly discovered AS links through LG servers compared with IRL, showed in Table II. As IRL had stopped updating since January 2015, we compared LG servers with Ark in terms of the newly discovered BGP links in Table I. It was easy to see that LG servers discovered more new links in 2018 compared to 2013 when the original paper was published. Even though we are using a different dataset from the authors, we can still point out the fact that the top 10 ASes of link discovery have completely changed since 2013. The tremendous increase on links found by LG servers showed that the Internet has indeed grown a lot while we are not yet to conclude that whether more LG servers were deployed in the past few years. In the authors' result, we see big company names that we are familiar with: Google, Microsoft, Facebook, etc. However in our result, we barely recognize any of the names. This could be attributed to the difference in the datasets we are making the comparison to. But as later we will see in Table III, Ark and IRL share a lot of overlapping AS links.

Another reason could be that big companies hid their AS links to BGP collectors such as LG servers.

TABLE I: Top 10 ASes in terms of the number of newly discovered AS links through LG servers that we found (2018). The number of AS links found in the Ark (2nd column), the number of newly discovered AS links from the LG servers (3rd column), and the corresponding increase in the AS connectivity in percentage (4th column).

AS Name (ASN)	In Ark	New in LGs	Percent Incr.
Hurricane (AS6939)	11772	2007	17.05%
Transtelecom (AS20485)	3437	855	24.88%
MF-MGSM-AS (AS31133)	2599	817	31.44%
ROSPRINT-AS (AS2854)	1144	628	54.90%
Cogent (AS174)	20384	615	3.02%
Level3 (AS3356)	24785	514	2.07%
NetVision (AS39737)	455	458	100.66%
Sul-Americana (AS25933)	479	445	92.90%
MTS (AS8359)	2685	430	16.01%
Akado-telecom (AS8732)	3545	402	11.34%

TABLE II: Top 10 ASes in terms of the number of newly discovered AS links through LG servers that Khan et al. found (2013)

AS Name (ASN)	In IRL	New in LGs	Percent Incr.
Level3 GBLX (AS3549)	3,290	112	3.40%
Abovenet (AS6461)	1,119	109	9.74%
Google (AS15169)	164	31	18.90%
Globalnet (AS31500)	115	29	25.22%
GlobalSol. (AS12713)	86	27	31.40%
Microsoft (AS8075)	122	27	22.13%
Yahoo (AS10310)	150	23	15.33%
Amazon (AS16509)	132	22	16.67%
EdgeCase (AS15133)	112	19	16.96%
Facebook (AS32934)	99	19	19.19%

TABLE III: The number of overlapping and unique (in bold) AS links between various AS topology datasets that we found (2018)

Source (Links)	LGs	IRL	IRR	Ark	iPlane
LGs (135K)	**28K**	64K	52K	92K	41K
IRL (573K)	64K	**265K**	119K	252K	135K
IRR (237K)	52K	119K	**85K**	100K	52K
Ark (748K)	92K	252K	100K	**369K**	211K
iPlane (439K)	41K	135K	52K	211K	**215K**

When it came to the unique AS links for each topology, we discovered 28K unique AS links that were hidden from other dataset (Table III), while the original paper found 11K unique AS links (Table IV). From these tables we could also see the numbers of unique AS links for other topologies, as well as the number of common AS links between any two topologies. From these two tables, we can also see big increases on almost all datasets. But we noticed that compared to other datasets, AS links found by LG servers increased much less. Other datasets usually experienced almost 10 times of increase, while

TABLE IV: The number of overlapping and unique (in bold) AS links between various AS topology datasets that Khan et al. found (2013)

Source (Links)	LGs	IRL	IRR	Ark	iPlane
LGs (116K)	**11K**	99K	46K	67K	45K
IRL (179K)	99K	**51K**	62K	75K	48K
IRR (160K)	46K	62K	**93K**	36K	24K
Ark (116K)	67K	75K	36K	**30K**	51K
iPlane (81K)	45K	48K	24K	51K	**25K**

LG servers only increased less than 300%. We speculate that it is due to the prevalence of other BGP feeders, LG servers did not grow a lot. Although we found more links to LG servers than the author, some of them can not be opened or did not support BGP command. The final valid LG severs were almost the same scale as the author used. Thus the increase of LG servers is much less than other datasets.

B. *Overlapping/Unique ASes*

TABLE V: The number of overlapping and unique (in bold) ASes between various AS topology datasets that we found (2018)

Source (ASes)	LGs	IRL	IRR	Ark	iPlane
LGs (64K)	**5.9K**	46.4K	36.8K	53.8K	31K
IRL (60.3K)	46.4K	**1.4K**	36.8K	57K	37.9K
IRR (47.8K)	36.8K	36.8K	**3.9K**	39.3K	24.7K
Ark (66.9K)	53.8K	57K	39.3K	**1.2K**	37.5K
iPlane (38.1K)	31K	37.9K	24.7K	37.5K	**146**

TABLE VI: The number of overlapping and unique (in bold) ASes between various AS topology datasets that Khan et al. found (2013)

Source (ASes)	LGs	IRL	IRR	Ark	iPlane
LGs (45.4K)	**686**	44.1K	28.7K	36.9K	25.4K
IRL (44.9K)	44.1K	**181**	28.8K	37.1K	25.5K
IRR (36.9K)	28.7K	28.8K	**6.2K**	24.5K	17.4K
Ark (37.1K)	36.9K	37.1K	24.5K	**-**	23.6K
iPlane (26K)	25.4K	25.5K	17.4K	23.6K	**281**

Similarly, we made comparisons for number of unique ASes for each topology. We found 5.9K unique ASes that had been undiscovered (Table V). Khan et al. found 686 unique AS in their study (Table VI). Our finding of the unique AS number is a huge increase from the original paper. Furthermore, the number of unique AS found through LG servers is the highest among the five topologies. From these two tables and the previous AS links comparison tables, we could see that the growth of AS links are much more than AS number growth. We speculate that maybe the complexity of the Internet happens inside the AS. More and more AS has grown bigger and more complex inside instead of creating a new AS. Also, the unique ASes in other datasets are much less than LG servers, this means more overlapping data shared with those datasets except LG servers. We speculate that maybe LG servers are losing its popularity.

C. AS Degree Distribution

The author investigated whether the different methods of collecting AS topology resulted in different AS degree distributions. The AS degree means the number of neighbors of one AS. An AS degree distribution is the probability distribution of AS degrees. The author plotted the CCDF curves of AS degree distribution for each topology. We followed this idea and plotted the CCDF curves for the data we collected. From Fig. 3a we could see that ASes in IRL's topology graph had a higher probability of having more neighbors, which matched the result of the original paper in Fig. 3b. Fig. 4 showed that, compared to IRR, the topology derived from LG servers has a higher probability with very large number of AS degrees in both our comparison and the authors' comparison. Compared to Ark and iPlane, our LG server's result had a smaller overall AS degree while the authors' result had the same level of AS degree, showed in Fig. 5. It could be explained by the fact that both Ark and iPlane had grown a lot since 2013.

TABLE VII: Our AS Topologies VS. Paper's AS Topologies

LG(ASes)	**2013**	**2018**	**LG(Links)**	**2013**	**2018**
2013 (45.5K)	**8k**	37.5K	2013 (114)	**75.4K**	38.6K
2018 (64K)	37.5K	**26.5K**	2018 (135K)	38.6K	**96.4K**
IRL (ASes)	**2013**	**2015**	**IRL (Links)**	**2013**	**2015**
2013 (44.8K)	**0**	44.8K	2013 (176K)	**0**	176K
2015 (60.3K)	44.8K	**181**	2015 (573K)	175.9K	**397.1K**
IRR (ASes)	**2013**	**2018**	**IRR (Links)**	**2013**	**2018**
2013 (35.7K)	**5.1K**	30.6K	2013 (160K)	**55.5K**	104.5K
2018 (47.8K)	30.6K	**17.2K**	2018 (237K)	104.5K	**127.2K**
Ark (ASes)	**2013**	**2018**	**Ark (Links)**	**2013**	**2018**
2013 (38.8K)	**0.1K**	38.7K	2013 (111K)	**1.2K**	109.8K
2018 (66.9K)	38.7K	**28.2K**	2018 (748K)	109.8K	**638.2K**
iPlane (ASes)	**2013**	**2016**	**iPlane (Links)**	**2013**	**2016**
2013 (26K)	**0**	26K	2013 (75)	**0K**	75K
2018 (38.1K)	26K	**12.1K**	2018 (439K)	75K	**364K**

D. Growth of Internet

Table VII showed the unique part and overlapping part between our results and the authors' results in terms of number of ASes and AS links. For LG servers, our dataset was very different from the original paper. The reason could be that many LG servers used by the authors were not available to us today, and we also found many new LG servers that were not included in the authors' work. From other datasets, we could see a very clear growth in both number of ASes and number of AS links. The same conclusion could also be drawn from Fig. 6 and Fig. 7. Even though the sizes of our LG server's topology and authors' LG topology were quite similar, other datasets showed a clear increase of the largest AS degrees.

VI. Conclusion

Overall, we found 28K AS links and 5.9K ASes that were hidden from other AS topology collection methods before. It demonstrates that Looking Glass servers are good supplement to the current AS topologies. Our results were highly aligned with author's results. We also showed the growth of AS-level topology corresponding to the development of the Internet since 2013 by comparing our data with author's.

In this project, we've face limitations in scraping information from LG servers. Some LG servers used by the author are not available today. For those servers that we can can still access, many of them don't support BGP commands or scripts are not allowed to fetch data from them. We also failed to extract information from some HTTP responses. Without a universal support of BGP commands and a comprehensive collection of LG servers, it could be difficult to derive a complete AS-level topology just from LG servers.

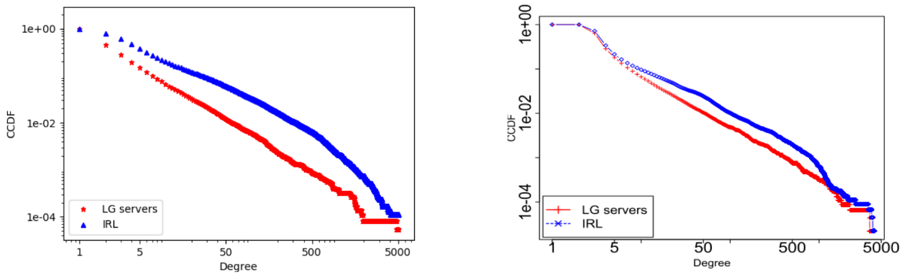
In addition, the degree evaluation itself isn't a comprehensive representation of the AS-level topology itself. As pointed out by [15], mere degree distribution does not paint a full picture of the AS-level topology.

Acknowledgment

This project is accomplished for CS513 Introduction to Local and Wide-Area Networks at Worcester Polytechnic Institute, instructed by Professor Krishna K. Venkatasubramanian in fall 2018. Our paper is an attempt to recreate the results from [1].

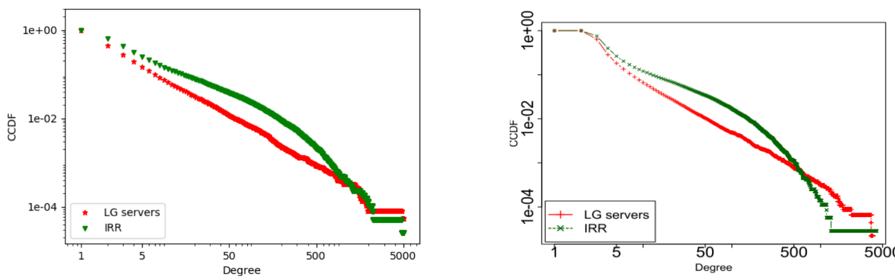
References

[1] A. Khan, T. Kwon, H.-c. Kim, and Y. Choi, "As-level topology collection through looking glass servers," pp. 235–242, 2013.
[2] Y. Rekhter, T. Li, and S. Hares, "A border gateway protocol 4 (bgp-4)," Tech. Rep., 2005.
[3] UCLA IRL, http://irl.cs.ucla.edu/topology.
[4] RouteViews, http://www.routeviews.org.
[5] RIPE-RIS, http://www.ripe.net/ris.
[6] Packet Clearing House, https://www.pch.net/resources/data.php.
[7] Internet2, http://ndb7.net.internet2.edu/bgp.
[8] CAIDA ARK, http://www.caida.org/projects/ark.
[9] H. V. Madhyastha, T. Isdal, M. Piatek, C. Dixon, T. Anderson, A. Krishnamurthy, and A. Venkataramani, "iplane: An information plane for distributed services," pp. 367–380, 2006.
[10] Internet Routing Registry, http://www.irr.net.
[11] E. Gregori, A. Improta, L. Lenzini, L. Rossi, and L. Sani, "On the incompleteness of the as-level graph: a novel methodology for bgp route collector placement," pp. 253–264, 2012.
[12] R. Oliveira, D. Pei, W. Willinger, B. Zhang, and L. Zhang, "The (in) completeness of the observed internet as-level structure," *IEEE/ACM Transactions on Networking (ToN)*, vol. 18, no. 1, pp. 109–122, 2010.
[13] B. Zhang, R. Liu, D. Massey, and L. Zhang, "Collecting the internet as-level topology," *ACM SIGCOMM Computer Communication Review*, vol. 35, no. 1, pp. 53–61, 2005.
[14] BGP Looking Glass Database, http://www.bgplookingglass.com/.
[15] H. Haddadi, D. Fay, A. Jamakovic, O. Maennel, A. W. Moore, R. Mortier, M. Rio, and S. Uhlig, "Beyond node degree: evaluating as topology models," *arXiv preprint arXiv:0807.2023*, 2008.



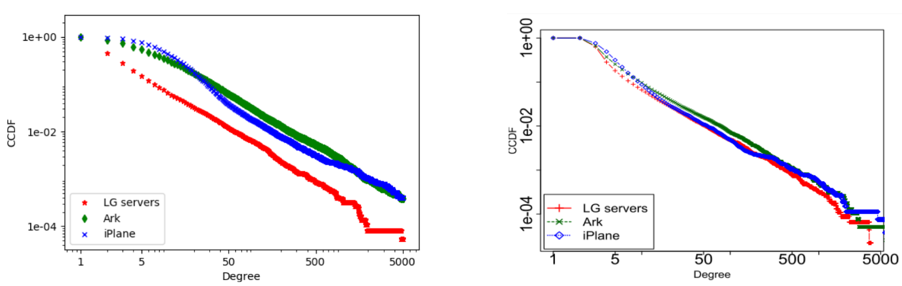
(a) Our result (b) Author's result

Fig. 3: AS degree distribution (CCDF) of the AS topology obtained from LG servers compared to IRL dataset.



(a) Our result (b) Authors' result

Fig. 4: AS degree distribution (CCDF) of the AS topology obtained from LG servers compared to IRR dataset.



(a) Our result (b) Author's result

Fig. 5: AS degree distribution (CCDF) of the AS topology obtained from LG servers compared to Ark and iPlane datasets.

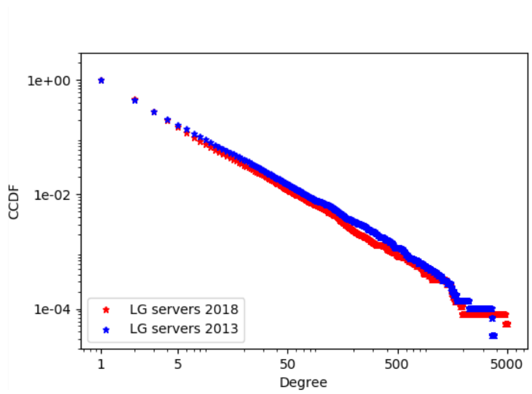
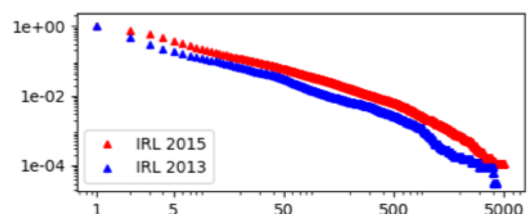
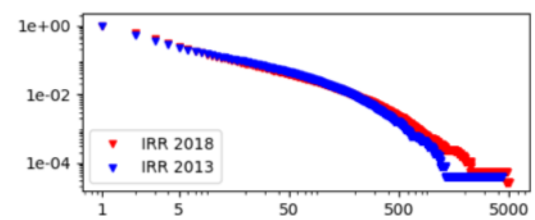


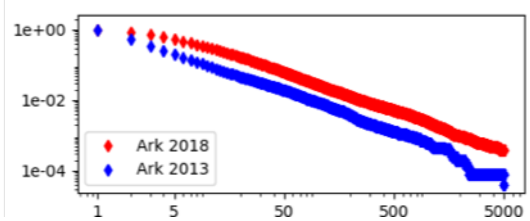
Fig. 6: AS degree distribution (CCDF) of LG servers



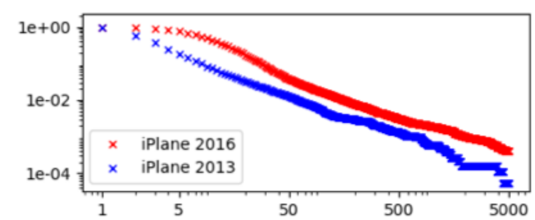
(a) IRL



(b) IRR



(c) Ark



(d) iPlane

Fig. 7: AS degree distribution (CCDF) of other topologies